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Abstract

Kinetic Studies and Control of Nuclear Reactors by Statistical Methods

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The statistical analyses of nuclear reactors are given by both direct power spectrum measurement method and crosscorrelation method using binary noise. The experimental and analytical studies of reactor kinetics by those methods are summarized, with a special emphasis placed on noise spectrum of various reactors at critical and subcritical states by direct measurement and on the development of binary noise techniques.

Finally, the automatic start up of a research reactor by digital method is described.

The noise analysis of JRR-1 (water boiler type) was performed by band pass filter method at various power levels (0.5 W to 40 KW) and also by digital autocorrelation method at 40 KW. Combined with the results of pile oscillator method, Cohn's noise model is valid below 50 W, and at high power levels a couple of peaks appeared in low frequency region, one of which agreed with that obtained from Moore's model as well as Skinner-Hetrick's model. However, the other peak, which is not explained by Moore's model, seems to be caused by the void fluctuation due to radiolytic water decomposition.

Reactor power frequency spectrum measurements of HTR (swimming-pool type)

at various power levels (0.2 W to 100 KW) were made by band pass filter method with twin-T filters and speed-up techniques of tape recorder. At high power some of the resonance peaks were found in low frequency region. The absolute value of reactor power obtained by noise analysis based on Cohn's noise agreed below 5 KW with the indication of power meter.

A reactor noise analysis during shutdown transient has been proposed to determine negative reactivity of TTR-1 (swimming-pool type). In order to obtain high neutron flux level at subcritical state and to be free from the spatial effect of ordinary neutron sources, it was tried to obtain frequency spectrum of reactor noise by band pass filter method with a magnetic tape recorded while the power is decreasing by rod drop with a constant period associated with the longest delayed neutron decay constant. Experiments were made under several shutdown conditions. The observed break frequencies were equated to the theoretical formula, $\frac{\beta}{\ell}(1+\frac{\rho}{\beta})$, then negative reactivity was estimated from that equation with other parameters determined from a critical experiment.

The reactor transfer function measurements by the crosscorrelation function between reactor power and reactivity input has been carried out using reactivity variation in the form of several types of binary noise. First of all the random interval and the discrete interval binary noises are compared. From the bandwidth viewpoint, the latter is favorable. An error analysis, however, showed that pseudo-random binary noise of maximum period sequence is preferable to the real random ones. A custom-designed reactivity generator is driven by the binary noise recorded on magnetic tapes. The reactivity and the reactor power are recorded on magnetic tapes simultaneously. Both analog and digital techniques are used to compute the crosscorrelation function.

The automatic start-up of the TTR-1 from source level up to power level is made possible with a digital computer. A specially designed digital computer counts pulse signals from BF_3 counters every Δt seconds, and at the same time calculates reactor period for indication and for control. Reactor period is calculated by an approximate formula. The approximate value thus obtained provides a more stable estimate of period especially at lower count rates than with a conventional analog periodmeter. The control signal is so determined that the speed of the control rod is in proportion to an error signal of inverse period.
The digital start-up control system described is a part of a program for establishing completely computer-controlled research reactor system. It will also assure safe operation of reactors.